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Loop Plant Electronics:

Physical Design Considerations

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The introduction of electronics into the loop plant has created the need for mounting electronic systems in the outdoors as well as in the central office. This article details the physical design considerations and requirements for the plug-in circuit boards, cabinets, closures, and hardware, and their interconnection to the telephone plant. Of particular interest is the product-line diversity from the small voice frequency range-extension devices and analog carrier systems to the large digital carrier and voice frequency loop switching systems. Each requires unique electrical and mechanical partitioning to optimize performance. Other critically important considerations are the cost-performance tradeoffs in a cost-sensitive market; the analysis, testing and evaluation of the system in environmental extremes of temperature, humidity, and atmospheric pollutants; the need to be compatible with existing loop plant hardware; and, lastly, the human factors considerations necessary to provide an effective interface with the telephone craftsperson. Specific designs are discussed which illustrate the practical problems encountered in meeting these requirements. In addition, the future thrust of loop electronics is discussed.

I. INTRODUCTION

Although electronics technology has been used for many years in the central offices and toll plant of the Bell System, its use in the loop plant is in its infancy. The first Western Electric loop electronic range-extension product, the 2A, was installed in central offices in 1968. Since that time, a complete family of loop electronic products has been developed, and its introduction has generated new challenges for physical design.

Unlike most Bell System electronic systems, certain elements of loop electronics hardware must be designed to mount outdoors (commonly referred to as the "outside plant") as well as in the central office. The central office is generally a controlled environment and is largely standardized from a facilities and craft point of view. The outside plant environment, on the other hand, has more variety in facilities including aerial, underground, and buried plant; a multiplicity of cable and cable apparatus with which the electronics must interconnect; and large variety in crafts: splicers, installers, linepersons, and repairpersons.

The aim of this paper is to highlight the central office and outside plant physical design of loop electronics products currently being manufactured by the Western Electric Company, Incorporated.

The loop electronics product line is diverse. Small carrier and voice frequency systems and large carrier and concentrator systems must be economically and ruggedly designed and packaged. Typically, the volume occupied at a remote terminal site varies from 135 cubic inches for a single channel analog carrier system to 16 cubic feet for a 40-channel digital carrier system. Since most loop electronic systems so far have been installed on rural routes, physical design has concentrated on aboveground mounting in the outside plant. This paper will deal primarily with these designs. As loop electronics penetrates the suburban and urban markets, the aesthetic pressure for out-of-sight plant will create a need to design for belowground installation.

II. PHYSICAL DESIGN REQUIREMENTS AND CONSTRAINTS

2.1 Overview

Providing basic electronic functions (logic, modulation, amplification, memory) while meeting all specified performance requirements is the key to any electronic system design. The physical designer must insure that requirements are not violated in partitioning the structure into various subassemblies, interconnecting the subassemblies, and packaging the system for mounting. This implies decisions that interact with reliability and cost in an extremely dynamic and cost-sensitive market.

2.2 Specific requirements [1]

2.2.1 Environment

The outdoor environment requires design to ambient temperature extremes of -40 to $120°F$ while accommodating both solar heating and internal heat generation by the electronics. Equipment must operate in ambient relative humidities up to 100 percent. The electronics must be protected from airborne particulates and pollutants including salt, dirt, hydrocarbons and industrial smog.

2.2.2 Human factors

The extremely labor-intensive loop plant requires special attention to a person's abilities to perform simple installation, operational, and maintenance tasks. The goal is to develop systems in which the hardware complements the skills of the people using them. This is a necessity in loop electronics because the hardware is being introduced into a working cable plant where job classifications are rigidly defined, and new tools, hardware, and methods frequently require changes in established procedures.

2.2.3 Compatibility

The need to interface with existing telephone hardware requires compatibility in many areas. The necessity for electrical compatibility at input and output terminations is obvious. Less obvious is the need to fit standardized equipment formats in the central office and need to interconnect new electronic equipment to existing apparatus.

2.2.4 Flexibility

Within the demanding loop electronics market it is necessary to provide flexibility for new features. Product obsolescence must be continually evaluated and dealt with. Plug-in assemblies and modular techniques are required to simplify changes and modification and to facilitate introduction of lower-cost silicon integration techniques as new technologies develop.

2.2.5 Manufacturing

As a product line, loop electronics systems, although rapidly enjoying acceptance, are comparatively low runners compared to other transmission and switching systems. This has encouraged the use of existing hardware so that system costs can be reduced by piggybacking onto a large volume runner.

III. SYSTEM PHYSICAL DESIGN DESCRIPTIONS

3.1 Analog systems

The *SLC*™-1 single channel carrier and *SLC*-8 multichannel carrier systems are described in a preceding article.[2] Both systems require central office and remote terminal equipment installations. The remote terminal ends of these systems differ significantly from each other in size and mounting locations. The *SLC*-1 mounts on the customer's premises; the *SLC*-8 in outside plant cabinets.

3.1.1 Central office equipment

The central office terminal equipment for *SLC*-1 and *SLC*-8 is illustrated in Fig. 1. Central office equipment design, for both, is relatively standard. The design format is simply described as a printed wire board plug-in (called a circuit pack) that plugs into a bay-mounted shelf. The *SLC*-1 and *SLC*-8 shelves mount in 23-inch-wide unequal flange, bulb

SLC™-1

SLC™-8

Fig. 1—Central office terminal equipment.

angle, or duct type frames. Mounting in wider bays like the ESS bay, for example, requires special mounting brackets.

The shelf designs for both systems take advantage of existing high-runner transmission products. *SLC*-1 uses a standard sheet metal shelf and separable backplane design developed for the F Signaling and Metallic Facilities Terminal systems. The steel shelf and backplane are illustrated in Fig. 2. To achieve low hardware costs, the typical individual card frame holder and faceplate were eliminated from the circuit pack. Instead the printed wire board slides into a new, low-cost plastic track that snaps into the standard mounting shelf. An attractive, blue, brushed aluminum common front cover replaces twelve individual circuit pack faceplates. Circuit pack cost is kept low by using single-sided printed wire boards and custom Western Electric Transmission Equipment Dips (TEDs). The TEDs are unique in that thin film resistors are functionally trimmed during TED manufacture to eliminate costly hand selection of discrete resistors during circuit pack assembly. The circuit packs are interconnected to the central office battery and equipment frame by wire wrapping to a Western Electric 928-type, gold finger, plug-in connector mounted to the F-signaling backplane. To save connector costs, the 928D connector was designed with contacts on one side only to match the single sided printed wire board.

The *SLC*-8 central office terminal consists of a bay-mounted shelf and a fuse and alarm panel. Nine circuit packs comprise one system: eight channel units and one power supply. *SLC*-8 takes advantage of a new, low profile line interface hybrid transformer for increased shelf packaging density, allowing 18 circuit packs per shelf. The standard D4 system shelf that is used has the required slot pitch. Figure 3 illustrates the equipment components. The D4 shelf is a die cast aluminum structure designed for frameless circuit packs. Its high-volume production lets *SLC*-8 share the economies of scale. To establish a family appearance with *SLC*-1, a similar common cover is used instead of individual faceplates. The *SLC*-8 circuit packs utilize the Western Electric 963B-20 socket connector, replacing the traditional gold finger plug-ended printed wire board. The *SLC*-8 backplane is a single-sided printed wire board that requires no hard wiring. The 3/32 epoxy glass backplane mounts directly to the D4 shelf. Also shown is the required fuse and alarm panel.

3.1.2 SLC-*1 subscriber premises apparatus*

Both indoor- and outdoor-mounted subscriber premises electronic packages have been designed for *SLC*-1. To achieve a small package, using standard low-cost electrical components, a novel manufacturing technique was introduced in which a rigid epoxy printed wire board is folded in the final manufacturing step to reduce the frontal area of the

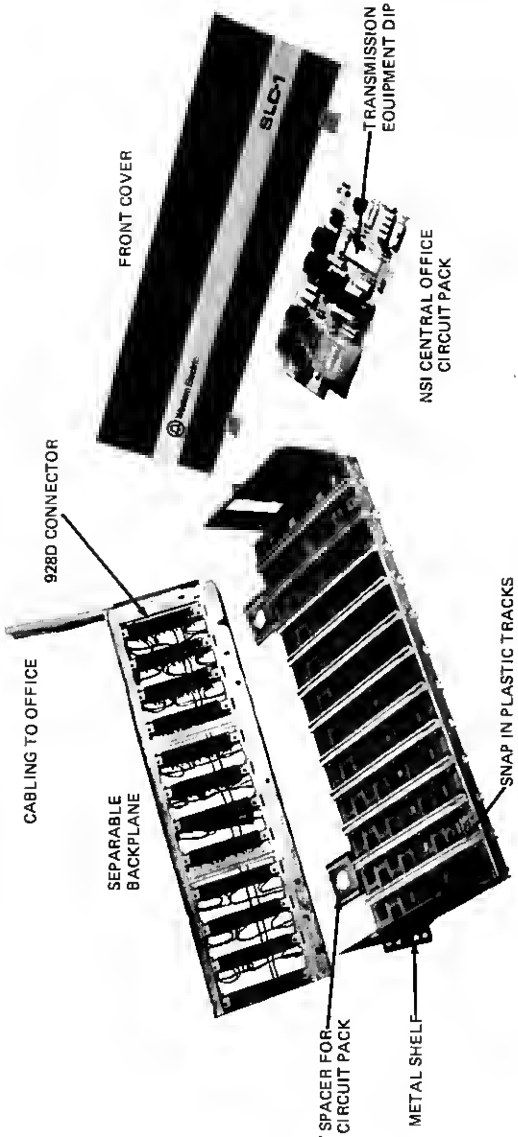

Fig. 2—*SLC*™-1 central office shelf components.

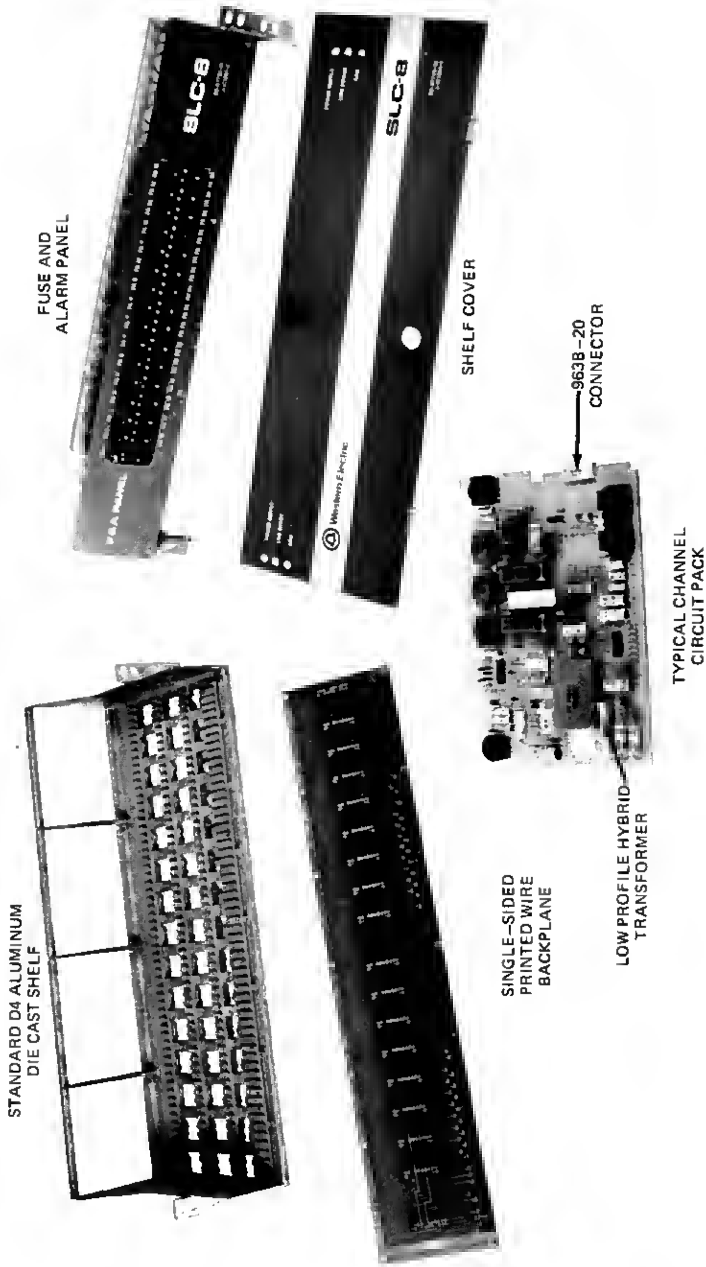

Fig. 3—*SLC*™-8 central office components.

package. Figure 4 illustrates the technique. The printed wire board is manufactured and tested flat, then sheared apart and folded. A flexible ribbon cable provides electrical connection between the two pieces. In addition, snap-on plastic posts provide mounting for a nickel-cadmium battery that powers the unit.

To further reduce costs of the indoor-mounted unit a standard gray plastic cover is used to protect the electronics. The cover is injection molded from a polyvinyl chloride (PVC) resin and is illustrated in Fig. 5. It is in common use in other Bell System applications.

The outdoor mounted unit required a custom design for the harsher external environment. A vented, bell-type-housing closure is injection molded from an ABS*/PVC blended material already being used for other loop closures (see Section 3.4.2). Material cost, required detail, weatherability, and aesthetics determined this selection. Injection molding a one piece closure with a 6.5-inch-deep cavity required careful mold design and balanced plastic flow. The closure is illustrated in Fig. 5.

The ABS/PVC thermoplastic was selected for these characteristics:

(*i*) Good weatherability, including ultraviolet light (UV) and oxidative stability. A dark color (charcoal gray) with a high carbon black content provides the UV protection.

(*ii*) High impact strength and flame retardancy at reasonable cost.

(*iii*) Acceptable tolerance to solvents, sprays and paints commonly used in a household or by a craftsperson.

(*iv*) Acceptable high temperature performance in ambient temperature extremes in the United States. Actual solar heating temperature increases to 187°F were recorded in the Southwest desert on the top surface of the closures, without distortion.

The same circuit pack is used in both the indoor and outdoor units. A standard epoxy-base solder resist cover coat (PC401†) protects the printed wire paths. The coating serves two functions. It protects the wire paths from contamination during manufacture and it aids the wave soldering of the circuit pack. Short term, high humidity (95 percent RH and 90°F) chamber tests and field trials comparing solder resist coated and noncoated circuit packs have demonstrated superior functional performance of the solder resist coated printed wire boards.

To assist the craftsperson during installation, the outdoor unit integrates the electronics and a standard station protector (123A1A protector block) within a single closure. Because the electronics are preterminated

* Acrylonitrile butadiene styrene.

† Western Electric specification WL2333.

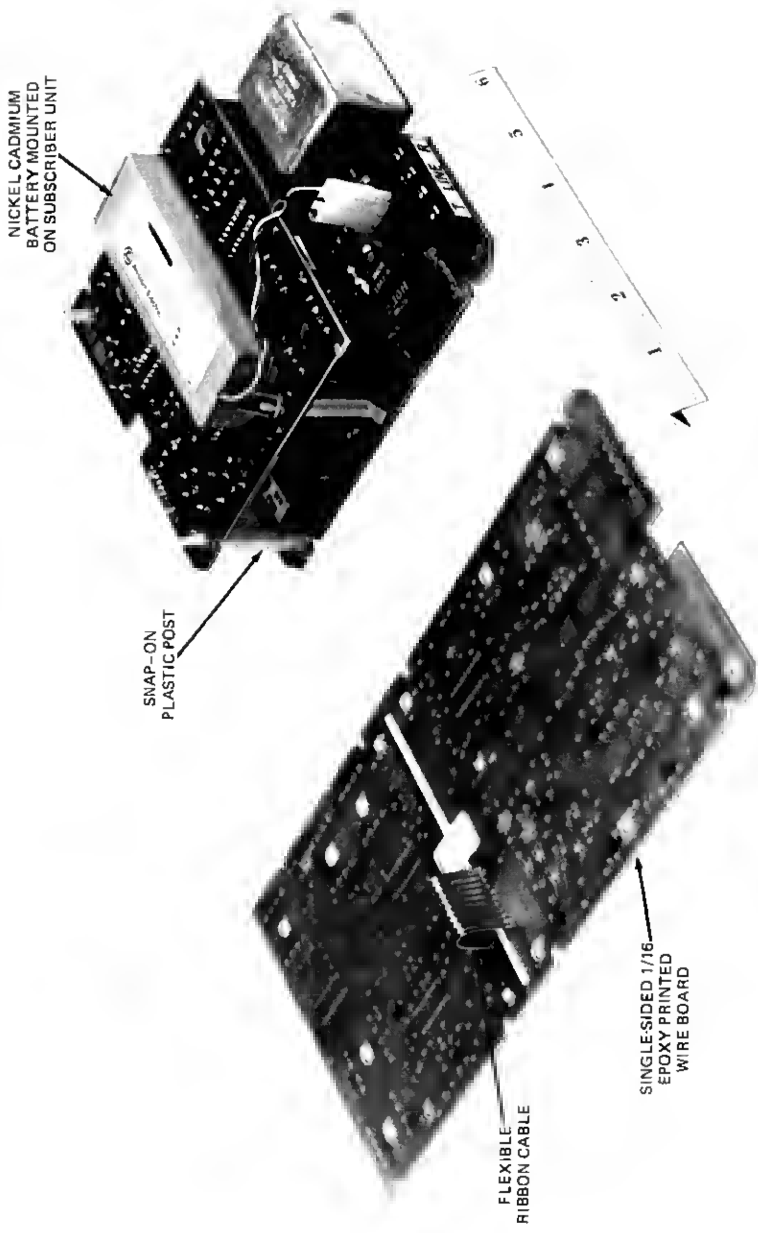

Fig. 4—*SLC*™-1 subscriber circuit pack.

Fig. 5—*SLC*™-1 subscriber premises electronics.

at the factory, the installer need terminate only the drop wire and station wire as in a standard main station installation (see Fig. 6). The mounting plate locates the closure-mounted protector unit at the same level as the old protector to avoid the need for piecing out and splicing existing station wiring.

The *SLC*-1 hardware also includes a small isolation filter mounted in series on the VF cable pair. Because of its similarity to the voice frequency 28A ringer isolator mounting, filter physical design details are discussed in Section 3.4.2.

To further help the craftsperson during installation, tbe *SLC*-1 subscriber electronics have been packaged in a specially designed carton with simplified installation and troubleshooting instructions. These packages are illustrated in Fig. 5.

3.1.3 SLC*-8 remote terminal apparatus*

The *SLC*-8 remote terminals can serve groups of eigbt customers from one location or are distributed to serve sparsely populated rural areas.

The physical design of the "lumped" system is built around an eight-channel modular housing. The system is modular to permit grouping remote terminals in a variety of sizes for flexibility in growth and application. *SLC*-8 lumped installations use existing loop plant pedestals and cabinets. Standard cable terminating apparatus is used

Fig. 6—*SLC*™-1 main station termination using standard 216B tool.

to connect the electronics to the cable plant. This design approach achieves craft and hardware compatibility and reduces the need to learn new techniques.

Four lumped remote terminal installations are illustrated in Fig. 7. Each comprises a modular circuit pack housing, cabinet, and interconnect hardware.

The lumped, modular circuit pack housing is illustrated in Fig. 8. The housing is injection foam molded from a polycarbonate plastic. The foam molding process was selected primarily for the low pressure molding technique it employs. Low pressure tooling is less expensive than that

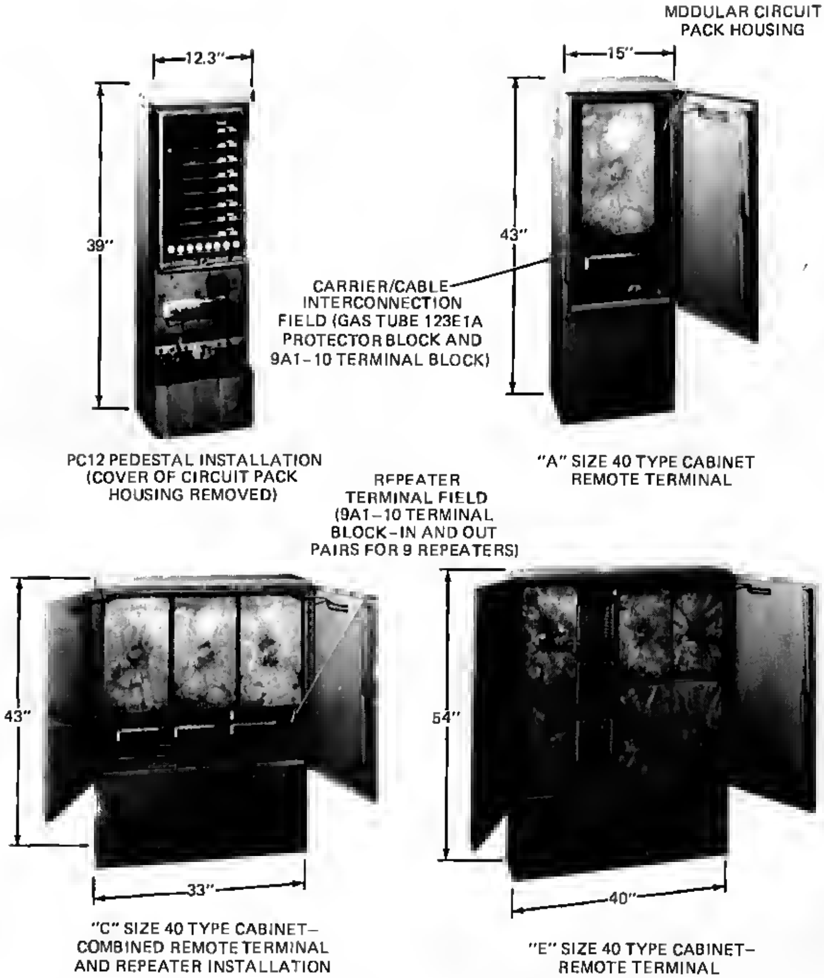

Fig. 7—*SLC*™-8 lumped remote terminal hardware.

for normal injection molding. Because the molding press must react against only the expanding plastic, the internal mold pressures are in the 200–400 psi range. Smaller tonnage presses and less expensive aluminum tooling can be used than for standard injection molding. Low pressure molding also reduces molded-in stresses. This produces parts with less distortion and permits more intricate detail for large parts.

Injection molding reduces secondary operations during manufacture by permitting functional details to be molded in. For example, tracks for the circuit packs, mounting bosses and holes to mount the printed circuit backplane, a molded-in hinging arrangement for the door, and details for locating and supporting accessory hardware can be molded.

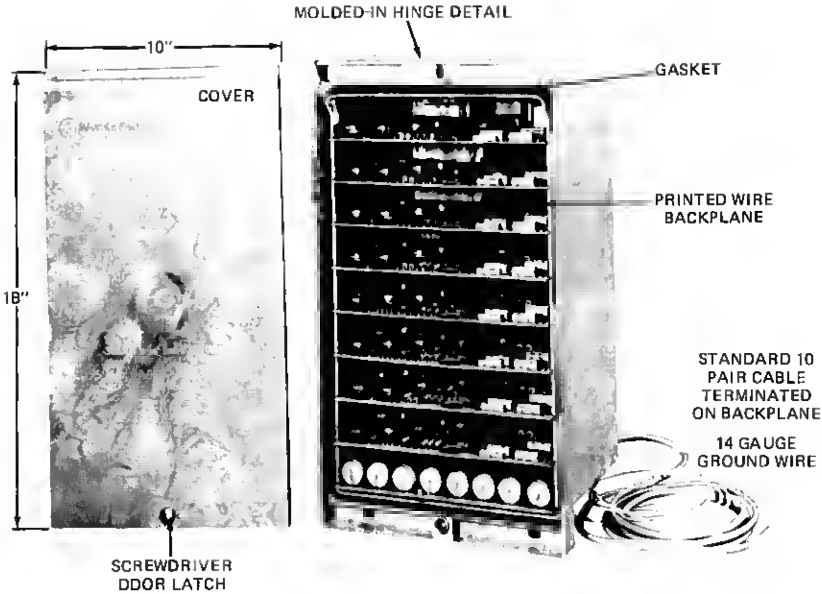

Fig. 8—*SLC*™-8 circuit pack housing.

The multiplicity of molded-in detail requires careful attention to tolerance limits. Of special concern was the circuit pack fit in the molded tracks and the mating with the rigid 963B-20 hackplane connector.

A polycarhonate molding compound was selected because of its inherent dimensional stability, low shrinkage rate, toughness, impact strength, and fire retardancy. Fire retardancy is important because the modular housing will occasionally be mounted inside huildings.

Foamed parts produce a swirl finish that may be objectionable. Surface finish in this application was not critical, however, because the housing mounts inside a cahinet.

The lumped housing is gasketed with an EPDM (ethylene propylene diene monomer) closed-cell ruhber foam for protection from dust, industrial pollutants and liquid water. This material comhines low closing force and long term dimensional recovery characteristics after compression, even under accelerated high temperature testing. In addition, EPDM rubber is significantly more ozone resistant than neoprenes, providing longer service life.

The unit is not sealed, hut hreathes with the atmosphere through a small opening in the hottom. The door latch requires a screw driver for entry. A twisted wire, paired cahle provides for connection to the cahle plant.

The remote terminal housings mount in the standard PC12 Bell System pedestal and the new family of 40-type cabinets designed for Serving

Area Interfaces (SAIs) and Rural Area Interfaces (RAIs). The design philosophy for using existing cabinets includes:

(i) Need for flexibility: *SLC*-8 is a small channel carrier system for which the operating companies require a variety of mounting arrangement and sizes.

(ii) Low cost and craft compatibility: *SLC*-8 takes advantage of existing Western Electric and AT-Specification closures manufactured in reasonably high quantities. Craftspeople who have been using these closures in conventional cable installations need no new skills to install them for electronics applications.

The PC12 pedestal is used without modification and provides an inexpensive installation for a single lumped system. The pedestal is galvanized steel, finished with a green polyester coating. The pedestal provides the gross mechanical protection for the circuit packs and the interconnect hardware.

A series of 40-type cabinets have been coded specifically for *SLC*-8. Special mounting brackets have been added to support the circuit pack housings and the accessory hardware. These cabinets are fabricated from heavy gauge galvanized steel, and finished with an electrostatically deposited polyester coating. The cabinets offer pole or pedestal mounting for one, three, and six lumped systems. They provide substantial mechanical protection for the electronics. The pedestal models require concrete mounting pads.

Interconnection of the electronics to the outside cable plant is engineered for craft skill compatibility. For example, standard binding post terminating blocks provide termination and test access of the carrier pair and the eight derived channels. The carrier pair is protected by a standard 123-type protector block. All wire terminating and splicing is done with standard loop plant hardware.

In addition to the remote terminal installations, repeater installations have been designed with the same building blocks. Provision for in- and out-carrier pairs and gas tube protection on the circuit packs are the only differences. Each circuit pack housing holds nine repeaters. Repeaters are available in the PC12 pedestal and in the A and C size 40-type cabinet versions. Figure 7 illustrates a combined repeater and remote terminal installation.

Distributed capability is provided with a custom designed closure, coded in two versions, one that holds one remote terminal channel and the other for two repeaters. The housing is a one-piece metal closure, fabricated and finished like the 40-type cabinet, with galvanized steel and polyester paint finish. The internal structure is a foam-molded detail that provides support for the circuit packs. Craft access to the circuit packs is provided through one end. Termination access is from the other

end. The door design, locking, and gasketing are similar to the lumped housing. The structure is vented through one opening in the housing. The housing measures 12″ × 12″ × 5″ and pole-mounts at eye level. Standard binding post hardware is used as in the lumped housing. Figure 9 illustrates the design details.

3.2 Digital systems

The present digital subscriber carrier system is the *SLC*-40 system which has been described in a previous article.[3] The principal physical parts of the system are a central office terminal, a remote terminal, and an interconnecting digital repeatered line.

3.2.1 Central office terminal

The central office terminal for the *SLC*-40 system, shown in Fig. 10, consists of a channel bank, fuse/alarm and jack panels, and a number of printed wiring board plug-in units. As is true for most loop electronics systems, the bank design format is taken from an existing high production volume system. The shelf, connector system, and circuit-pack board outline are identical to the D3 channel bank system except for the height of the board. To avoid the costs of painting and marking faceplates for each plug-in unit, decals are used to give the specific designations required.

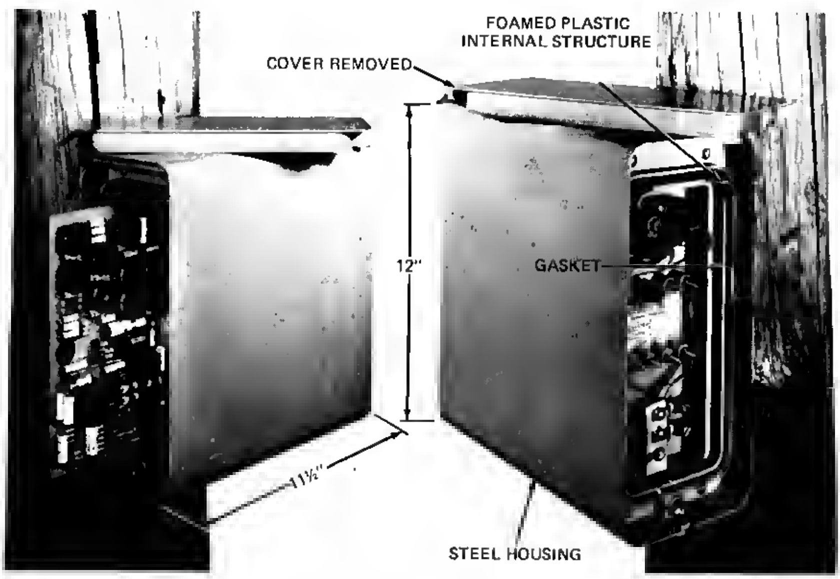

Fig. 9—*SLC*™-8 distributed remote terminal configuration; holds one *SLC*-8 channel.

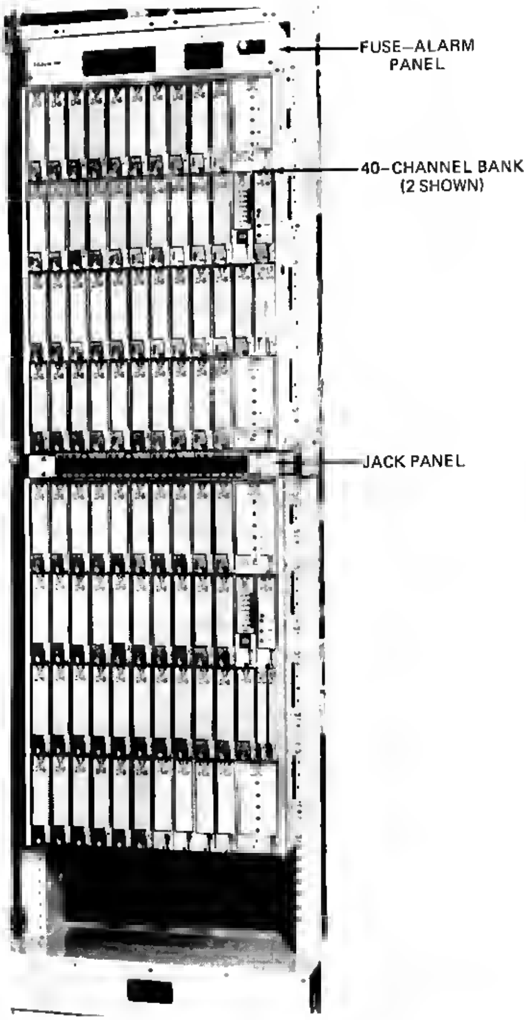

Fig. 10—*SLC*™-40 central office terminal.

As can be seen in Fig. 11, the interconnecting wiring in the system is a combination of conventional wire wrapped leads and printed wiring board backplane connections. Each of the common function circuit packs (multiplexer, power supply, etc.) requires unique wiring. Wire wrapped connecting leads are used for interconnecting these nonrepetitive circuit packs. There is, however, a great deal of commonality among the forty channel units that are used in each bank. Here, a simple double-sided printed wiring backplane is used with connectors having terminals suitable for mass soldering. The same printed backplane is used for both ends (COT and RT) of the system to further promote the advantages of

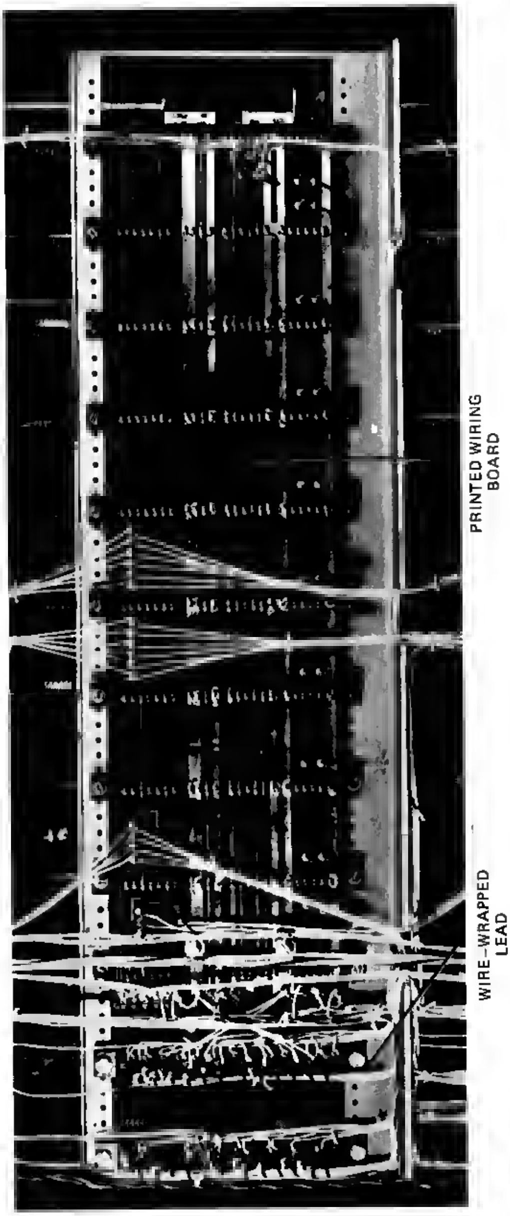

Fig. 11—*SLC*™-40 bank backplane wiring.

consistency and simplification of manufacture. Wire wrap terminals are provided for most of the external connections from the COT.

The bank and panel assemblies for the *SLC*-40 system are designed to be front mounted into a 23-inch equipment frame having a 5-inch front guardrail to upright dimension. This allows the use of such assemblies in virtually all of the older electromechanical Class 5 offices which often have bulb angle or other old style frames. Further, the COT equipment is only available as panel or bank assemblies, and not pre-mounted on equipment frames. This is done to minimize the Western Electric stocking inventory. It is necessary for Western Electric to be able to ship equipment directly from stock to achieve a 10-week delivery interval as opposed to the more conventional interval of 26 weeks or more.

3.2.2 Remote terminal

Two basic configurations are available for the *SLC*-40 system remote terminal. The RT may be mounted inside a building in a more or

Fig. 12—*SLC*™-40 cabinet remote terminal.

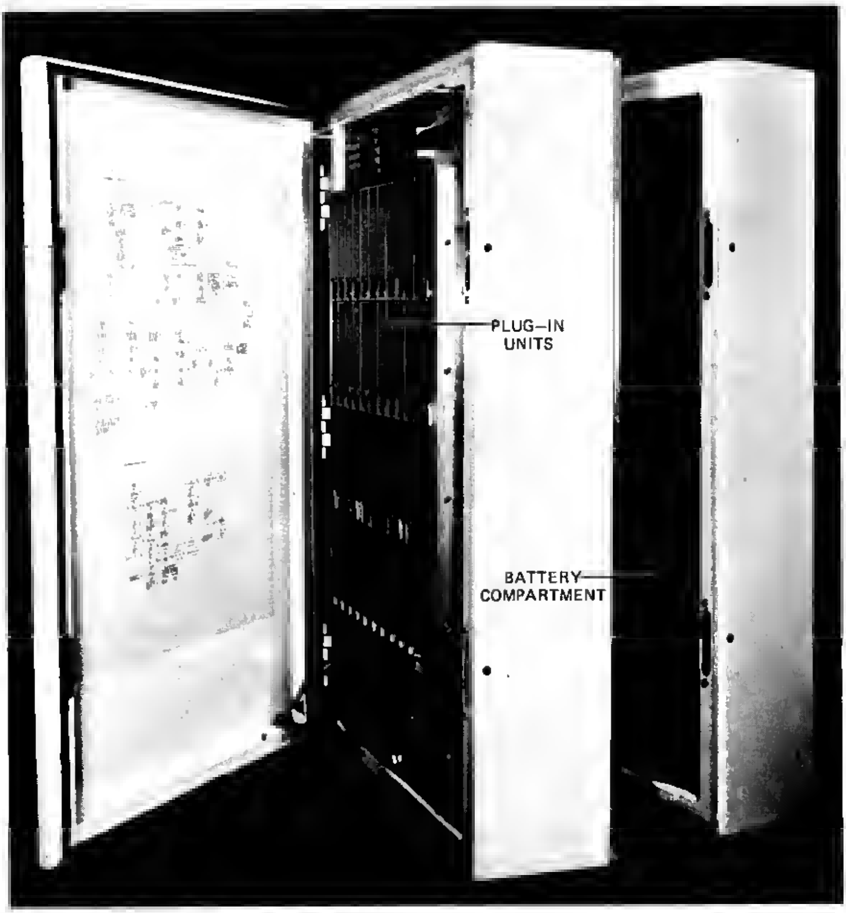

Fig. 13—*SLC*™-40 RT cabinet, both sections open.

less conventional equipment approach, or a cabinet may be used for outdoor mounting.

The RT cabinet system as shown in Fig. 12 is a rather large (4 ft. high, 16 ft^3 volume) unit. It operates from commercial ac power, has basic power conditioning and ringing generator capabilities, and contains a battery for reserve operation against the loss of commercial power. Finally, the RT performs the operations required of a digital channel bank.

The cabinet itself is a formed aluminum structure with hinging in two places as illustrated in Fig. 13. The front door allows access to the front of the bank to permit maintenance of the plug-in units. Further, the entire cabinet is hinged at about its midpoint to give access to both the rear wiring of the channel bank, and also the back cabinet section which houses the reserve batteries. The cabinet is capable of being mounted

Fig. 14—*SLC*™-40 RT cabinet, multiple cross-arm mounting.

on a pole, on a crossarm structure hetween poles, or on a pedestal mounted to a concrete pad (see Figs. 12 and 14).

For large systems such as this one, it has heen found that it is often more economic to provide environmental protection to the entire RT with one structure, as opposed to protecting smaller suhsections of the system. For this reason, the *SLC*-40 cahinet was designed to provide such protection. The cahinet has completely gasketed doors, provisions for diverting water which might penetrate a damaged gasket away from the electronics, as well as drains and vents to prevent humidity extremes inside the cahinet. Walls are capahle of withstanding 22 caliher rifle fire. Also, the *SLC*-40 RT dissipates approximately 100 watts inside the cahinet which serves to markedly decrease local relative humidity conditions, and hence reduce corrosion potential.

The same internal heating which helps prevent corrosion, however, can he trouhlesome in very hot sections of the United States. To further compound the thermal situation, solar heating must he allowed for. For the *SLC*-40 RT, a white exterior finish was used on the cabinet to minimize the amount of solar heating. White paint has the fortunate comhination of properties which give high thermal reflectance for solar radiation, yet high thermal emissivity for lower-temperature long-wave radiation.

The design of the RT channel hank is very similar to the COT. In fact, many of the common control plug-in units are used in hoth ends of the

system. A fifth shelf is used with the RT cabinet to mount the required ringing generator and rectifier.

The nickel-cadmium batteries used to provide reserve for the system require a number of design provisions. A heating system is required for the batteries to prevent extreme loss of capacity at cold temperatures. Small amounts of hydrogen are given off during normal float charging conditions, and this must be vented to the outside of the RT cabinet. The batteries must be accessible for periodic watering and cleaning, and electrolyte spills from leaking cells should be isolated from circuit ground to prevent excessive heating from fault currents.

The batteries are mounted within a separate enclosure in the rear of the RT cabinet as shown in Fig. 15. The enclosure is fabricated from steel, since this material is not attacked by the potassium bydroxide battery electrolyte. A silicone rubber resistance wire heater is bonded to the exterior of the door of the battery compartment. The battery temperatures are controlled by bi-metal switch type thermostats which are also mounted outside the compartment, but are closely coupled to the battery case temperature via a relatively low thermal impedance path offered by the conductance of the supporting shelf.

The battery compartment door is gasketed to separate hydrogen from the RT electronics. The battery compartment is separately vented to the

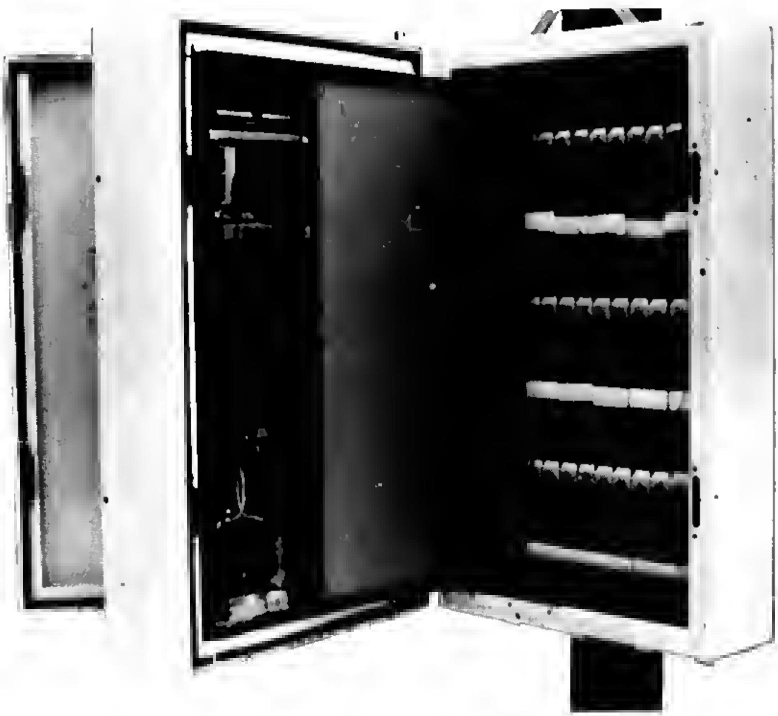

Fig. 15—*SLC*™-40 RT cabinet, battery compartment door open.

outside of the RT cabinet by two ports. The size and vertical separation of the ports are designed to allow buoyancy forces from density differences to induce sufficient flow to insure a nonexplosive state inside the compartment. Normal wind-induced siphoning further aids the dissipation of the hydrogen-rich air.

The battery compartment is electrically insulated from ground, and electrolyte flow paths are provided to conduct leaking electrolyte out of the RT cabinet, thus preventing fault current problems.

As mentioned earlier, a frame version of the RT is also available for inside mounting in customer premises equipment rooms or in small huts.

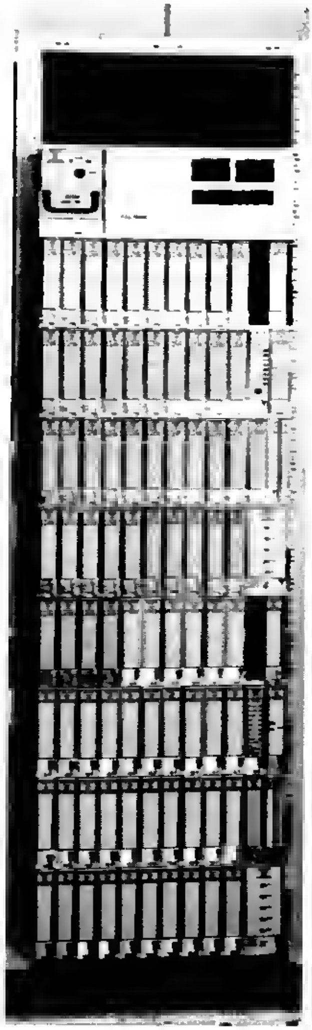

Fig. 16—*SLC*™-40 frame remote terminal.

As can be seen in Fig. 16, two 40 channel banks are mounted on a 7-foot frame with a common fuse/filter/ringing generator panel. The design format is identical to the cabinet-mounted RT bank. A separate source of dc power must be provided for the frame RT.

3.2.3 Digital line

A simplified digital line troubleshooting routine has been evolved for the *SLC*-40 system to ease maintenance for those areas unfamiliar with T1 fault location techniques. The simplified routine requires sequential visits to a number of repeater sites to change out and test the repeaters. Conventional repeaters and cases can be used with this routine, but a quick disconnect scheme was deemed more desirable. For this reason, and to enable a more economic installation of only a few repeaters at a site, a self-protected weather resistant repeater design was developed. This design, shown in Fig. 17, consists of a standard T1 repeater housed in a sealed box with gas tube protectors, and a quick disconnect type waterproof aircraft connector. As shown in Figs. 18 and 19, these repeaters are housed in small aerial or pedestal closures which give the appearance of conventional telephone plant apparatus, and allow easy access to the repeaters mounted inside.

3.3 Line concentrator system

This section deals with the Loop Switching System (LSS) which is also the subject of another article.[4] Again, the major physical entities consist of terminals for the central office and remote ends of the system.

3.3.1 Central office terminal

The LSS COT, illustrated in Fig. 20, is composed of three shelf assembly designs and a number of plug-in circuit packs. The shelf and plug-in unit format is taken from an earlier system (the Subscriber Loop Multiplexer system) which was compatible with the physical requirements for LSS. Thus, initial manufacturing capital outlay is minimized. Again as in the case for the *SLC*-40 COT, only shelf assemblies are offered to minimize the number of orderable units for stocking simplicity and to minimize the ordering interval.

The primary common control assembly is a combination of a shelf for plug-ins and a power-fuse-alarm-microprocessor panel. The two entities are combined into a single mechanical unit to simplify the interconnecting wiring required. Connectorized cables are used to interconnect this assembly to the other LSS shelf assemblies. Due to the variety of gauges and destinations, more conventional wire-wrap and screw-down terminations are used for the wires that connect to the central office power and alarm circuits.

A second common control shelf is required to house the power supply

Fig. 17—*SLC*™-40 quick-disconnect repeater.

Fig. 18—*SLC*™-40 pole-mounted repeater enclosure.

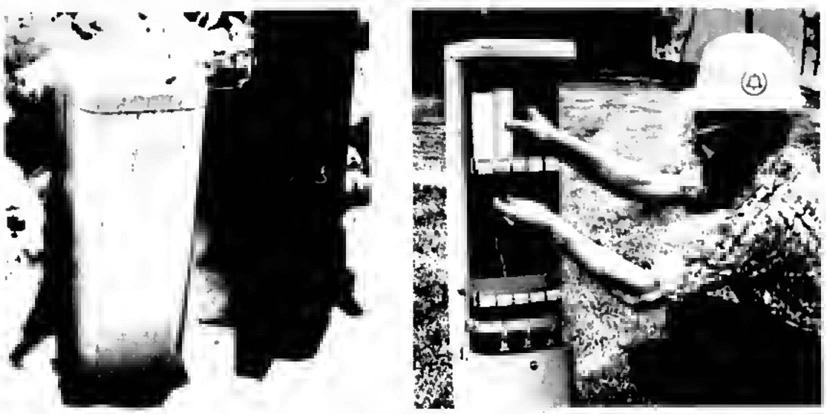

Fig. 19—*SLC*™-40 pedestal-mounted repeater enclosure.

and modem for a second remote terminal. This assembly connects to the system via connectorized cables to the primary common control, and is only provided when a double RT operating mode is used.

A pin-and-socket-type connector arrangement is used for the circuit packs on LSS. This is the 963-type connector mentioned earlier in the *SLC*-8 description. The socket part of the connector, shown in Fig. 21, is mounted on the circuit pack and is heat-staked and mass-soldered to the printed wiring board. Multiple numbers of 20 contact connectors are used on each unit depending on the number of connections required.

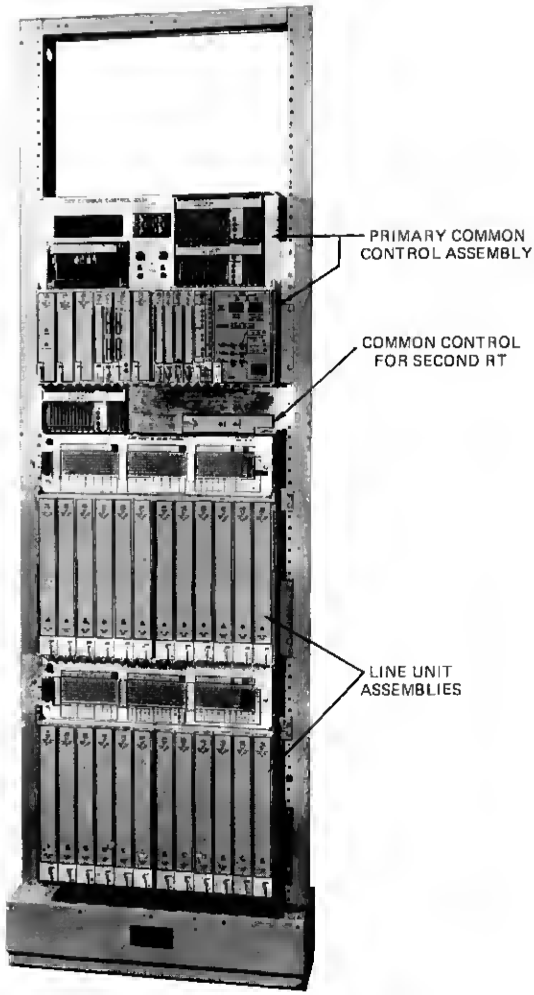

Fig. 20—LSS central office terminal.

The pin half of the connector, Fig. 22, is essentially a 0.025-inch-square post which is force fitted into a plated-through hole in a printed wiring board backplane. One end of the pin plugs into the connector socket, while the other end can be used as a wire-wrap terminal. Each group of 20 pins is provided with a plastic guide block to both physically protect the pins from damage and to provide alignment guidance between the pins and the socket connectors during plug-in engagement. Sequential engagement of circuit ground before any other connections is accomplished by making these pins longer. This prevents voltage breakdown of ungrounded devices.

Printed paths are used to provide much of the interconnecting

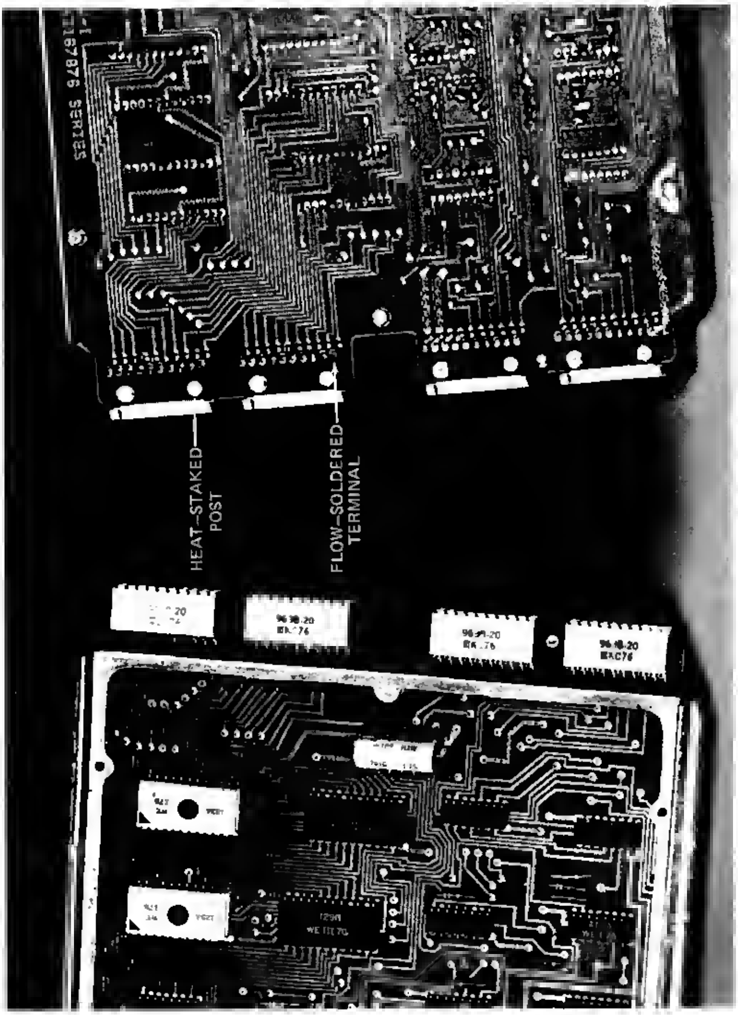

Fig. 21—LSS circuit pack connector.

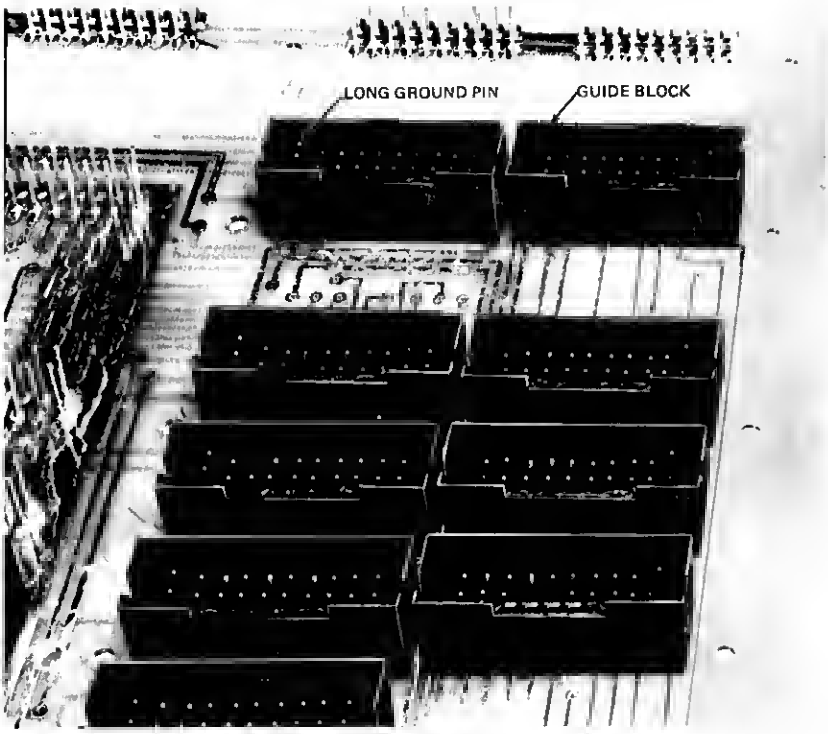

Fig. 22—LSS backplane connector pins.

intrashelf wiring required on the various shelves. Specifically, this accounts for more than 30 percent of all the factory-applied wiring for the system. All of the backplane printed boards are limited to only two wiring levels to avoid the expense of more costly multilayered boards.

The third shelf assembly design for the COT is the line unit assembly which mounts twelve identical line unit circuit packs. These circuit packs contain the relays that provide the switching network for a 96-line, 32-trunk system. These rather large, 14-inch-high, plug-in units have the components for eight subscriber lines on a single printed wiring board. The use of a single large board for eight lines instead of two or more smaller boards results in a substantial decrease in the number of connector contacts and interconnecting wires required for the switching network.

Testing access is provided to all line, trunk, and data link pairs through a compact field of terminals. These may be connected to a larger set of test terminals, as shown in Fig. 23, through a probe cord which is part of the assembly. External connections of lines, trunks and other control leads are also made from this assembly. These connections are all connectorized to allow ease of installation and replacement, and to simplify

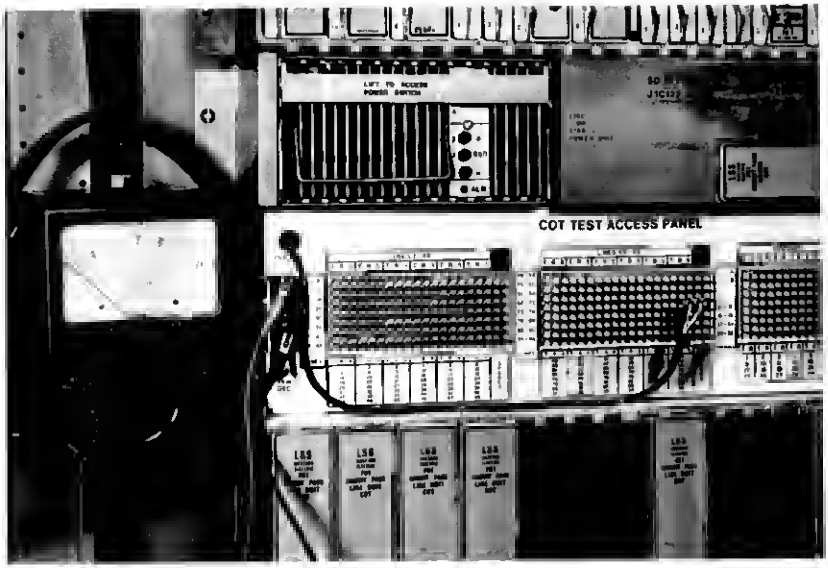

Fig. 23—LSS test access panel.

manufacturing testing. The connectors used mate with standard key telephone type connectorized cables to further simplify installation.

3.3.2 Remote terminal

The LSS remote terminal electronics can be mounted in a cabinet (Fig. 24) or on a conventional equipment frame for inside applications. In either case, the same two basic shelf assembly designs are required.

The RT common control assembly and the RT line unit assembly both use hardware and wiring formats which are identical to their COT counterparts. As in the COT, one common control assembly is used with either one or two line unit assemblies for a 96- or 192-line system, respectively. These assemblies by themselves constitute a functional, self-contained system.

The cabinet is a derivation of the *SLC*-40 system cabinet. The center section and door were retained, and the large rear section is replaced with a rear door. This yields a cabinet of about 10 ft^3 volume with a height of 4 feet. Mounting arrangements include both pedestal and crossarm versions.

The protective capabilities of the RT cabinet are identical to those discussed for the *SLC*-40 system with one exception. The differing characteristic is that the LSS dissipates only about 13 watts in the RT cabinet. This means that LSS is not as self-protecting against humidity as is the *SLC*-40 system. However, this has been somewhat compensated for by using a green exterior finish on the cabinet as opposed to the white finish used for the *SLC*-40 cabinet. The green finish has a higher solar

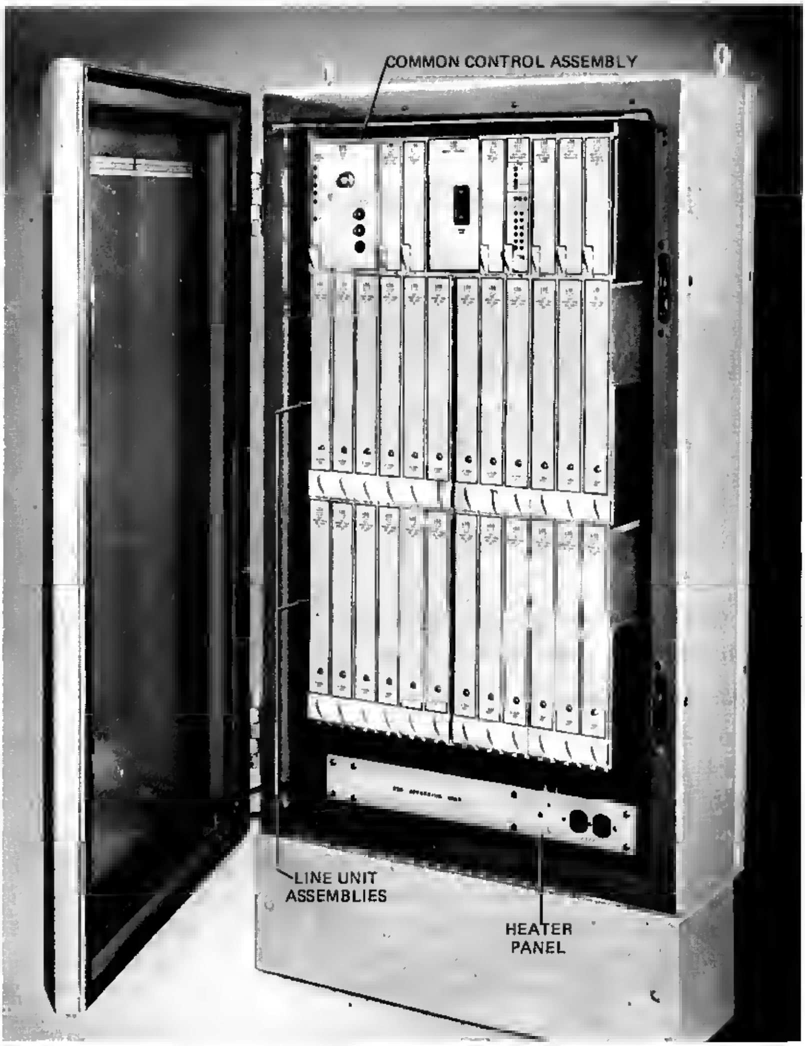

Fig. 24—LSS cabinet remote terminal.

absorptivity than a white finish and results in somewhat higher average internal cabinet temperatures than would be the case for a white cabinet, along with accompanying lower relative bumidity values. RT corrosion is only expected to be significant in areas where very high average relative humidities exist with high temperature. Such areas as the Southern United States, particularly in some sections of the Gulf Coast states, may require the use of a cabinet heater panel to provide the same degree of humidity control that exists in other systems.

The heater panel is powered from commercial 120 volt ac power, and as a result requires additional installation cost to provide such service.

Since the maximum persisting dew-point temperature in the continental United States is under 80°F,[5] the heater panel is designed to provide a temperature rise of 10° to 20°F for all ambient temperatures under about 100°F. The heater shuts off at ambients greater than 100°F to minimize power consumption and to prevent unnecessary heating at high temperatures. The 10° to 20°F temperature rise decreases the internal relative humidity to levels that greatly reduce corrosion rates.

Another influence on the physical design of the LSS has been the experience gained from prior systems that used open-contact switching networks in outdoor cabinets. Visions of dust, corrosion products, and freezing condensate causing blocked contact conditions have occasioned some rather strong reactions against any similar switching network. The switching relays in LSS have been protected against and extensively tested[6] for such problems. It has been found that a substantial degree of protection is provided by enclosing the relays in a closely fitting, but not sealed, enclosure.

The line unit circuit pack design, Fig. 25, provides a protective relay

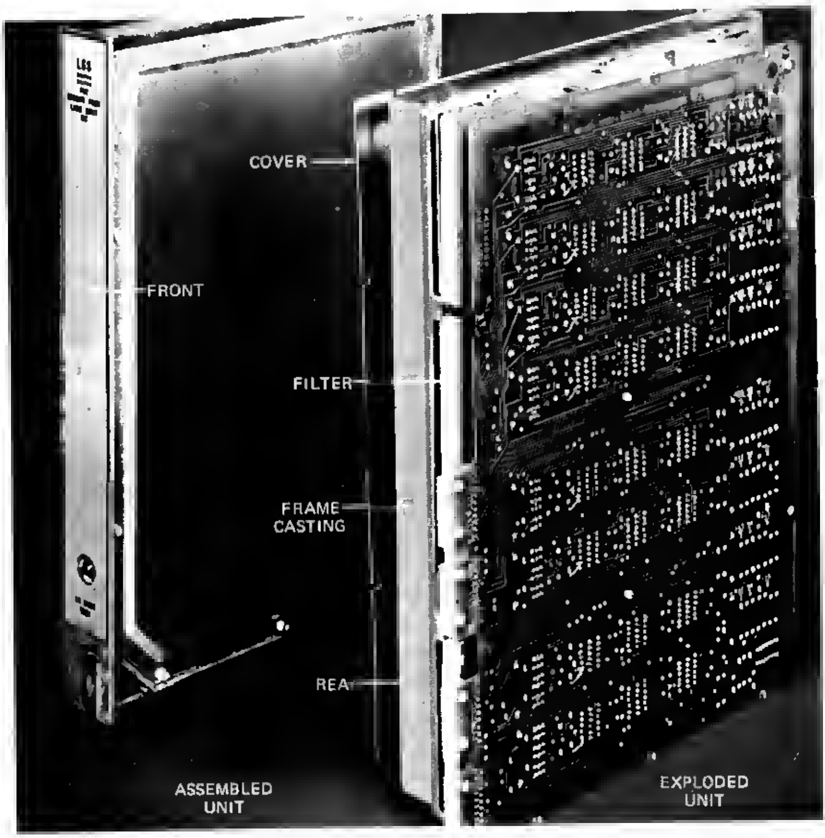

Fig. 25—LSS line unit circuit pack.

enclosure with a minimum of mechanical parts and accompanying cost. One side of the enclosure is formed by the printed wiring board that mounts the relays. Mass soldering of the components to the board results in the closing of virtually all through holes. An aluminum frame casting, to which the printed board is mounted, forms the next four sides. The rear surface has pockets to allow filter material to be held in compression between the frame and the board surface. The filter allows a vented enclosure in deference to outgassing from the relay coils, and at the same time excludes the larger sized dust particles and debris that have the potential to cause contact blockages. The sixth side of the enclosure is provided by a formed aluminum cover which is attached to the board frame.

The line unit circuit packs used in the COT are identical to the RT units except that the dust filters are omitted. The cover is retained for the COT units to provide an additional measure of mechanical handling protection.

3.4 Voice frequency electronics

3.4.1 Range Extension with Gain (REG)

Range Extension with Gain is described in a previous article.[7] The REG system differs from other loop electronic products in two ways. First, it consists of equipment mounted in the central office only; second, it has an extremely high annual production volume, currently about 250,000 circuit packs/year.

A REG system consists of a circuit pack that mounts in a transmission equipment bay. A REG is a per/line device and is wired into the loop between the switching equipment and the main distributing frame. It is powered by a circuit pack power supply mounted in the bay and wired to a bay-mounted fuse, alarm, and filter panel powered from the −48V central office battery.

REG has been available since 1972. Since that time, a number of circuit improvements and cost reductions have been made. Each REG has remained interchangeable with earlier models. Today the 5A REG is a single-sided printed wire board, contrasting with the first model, which required two printed wire boards. It was originally designed in the F-Signaling system format to take advantage of commonality in manufacturing facilities. Figure 26 illustrates the old and the new REGs. Circuit pack size is 8″ high by 10″ deep. To maintain compatibility with earlier REGs, the standard aluminum die-cast card frame is still used. Except for a precision thick-film resistor network, all electrical components are the traditional discrete variety.

Traditionally, REG bay equipment has been manufactured in factory-wired arrangements, although separate shelves are also available.

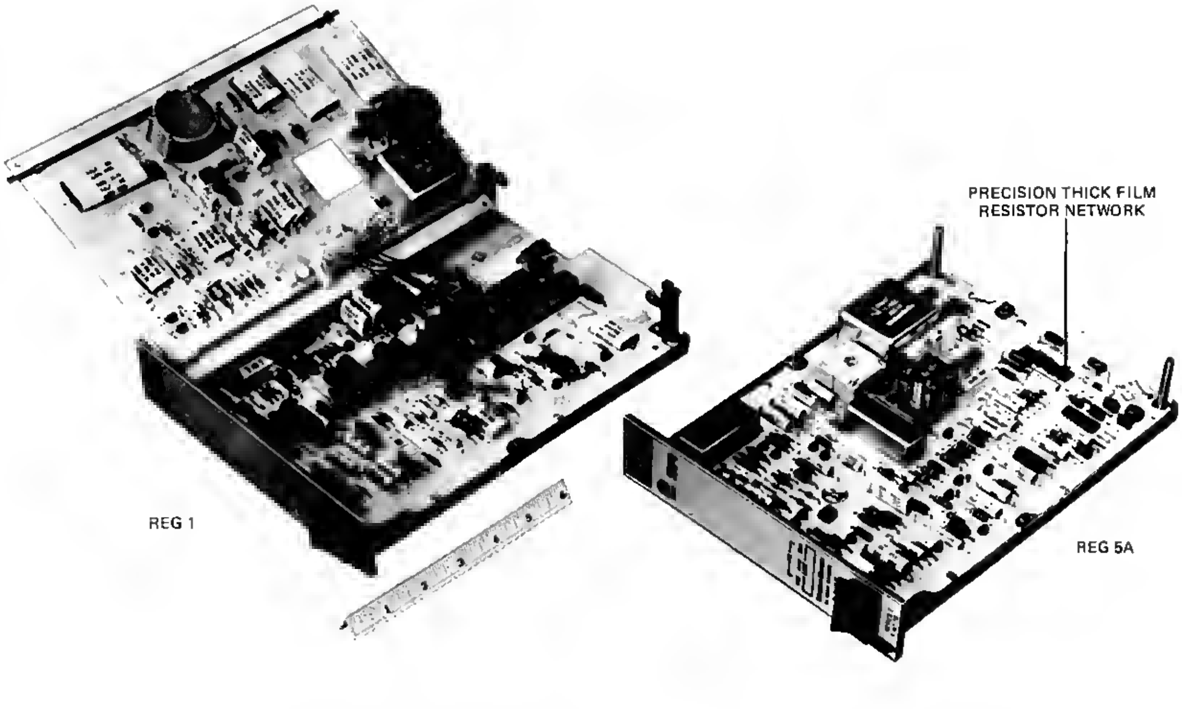

Fig. 26—REG circuit packs.

Fig. 27—REG bays, South Knoxville, Tennessee, central office.

These include 11′-6″ and 9′ bulb angle bays and 7′ and 11′-6″ unequal flange bays. A typical bay arrangement is illustrated in Fig. 27. An 11′-6″ bay serves up to 165 REGs. Interconnection of the circuit pack to tbe CO cabling is through a 908A gold finger connector mounted on the shelf. Intershelf and intrashelf connections are hard-wired using the wire-wrap terminals on the rear of the Western Electric 908A connector.

Through mid-1977 the standard one-piece die-cast F-Signaling shelf was used. With the introduction of the new F-Signaling steel split sbelf (see Section 3.1 on *SLC*-1), the REG bay bas been reconfigured into a modular format. This approach has reduced Western Electric manufacturing costs and added flexibility in telephone company ordering options. Tbe approach permits shelves of equipment to be incrementally ordered and plugged together in the field.

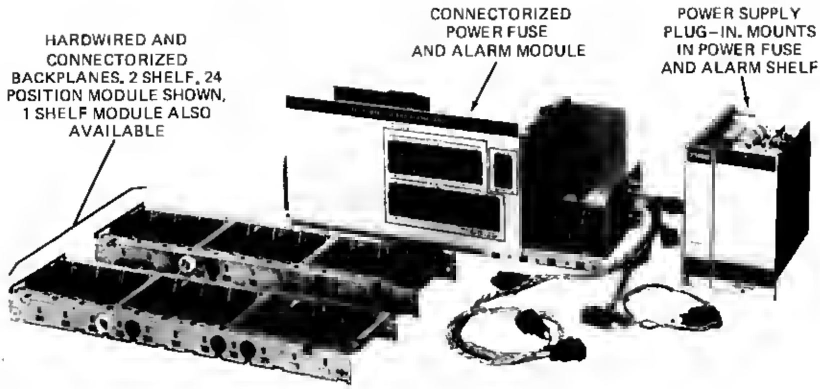

Fig. 28—Modular REG bay components.

The REC bay has now been structured into three modular units. One unit combines the 71A power supply, filter circuit and fuse and alarm panel into a standard F-Signaling shelf mounting. A connectorized cable interconnects it to each shelf of REG circuit packs. The other two units are hard-wired, connectorized backplanes that also mate with standard steel shelves. The modular building blocks are illustrated in Fig. 28.

The modular packages can be combined into any REG bay offering. Typically, a telephone company can select a vacant bay area in a central office and equip it with a multiplicity of steel shelves. Backplane units and power supply/fuse and alarm panel can be ordered as required, mounted on the shelf or bay and plugged together.

The modular format provides Western Electric with the capability to substantially reduce floor space allocated for manufacture and storage of bays. More automation can be introduced at a bench handling smaller units.

3.4.2 Ringer isolator and small closure design

The other segment of the voice frequency product line is the ringer isolator. A previous article[7] describes the need and usage of this device. The current Western Electric product is the 28A ringer isolator. The unit is a solid state circuit encapsulated in a small weatherproof housing which mounts next to the subscriber protector block.

The design objectives for the 28A were to produce a device with improved electrical performance compared to its predecessor, the 11A. That was accomplished with a reduction of size and cost by a factor of two.

Since the unit required weatherproofing to permit mounting on the outside as well as the inside of the subscriber premises, and because of its low price, it was decided to encapsulate it.

The 28A circuit comprises 25 components mounted on a $1.5 \times 3''$ single-sided, epoxy glass, printed wire board. Design guidelines for the

printed wire board manufacture by machine insertion were carefully observed and worked to the limits. A polyurethane encapsulation compound, blended from a polycin and vorite mixture, is used for encapsulation. This is the same compound used for the *SLC*-1 1119A isolation filter. A plastic case, similar to the one used on the 1119A, was designed for the 28A. The 28A and the 1119A are compared in Fig. 29. In production, both units are injection molded from the same tool.

The ABS/PVC blended thermoplastic, used on the 28A and *SLC*-1 outdoor closure, was evaluated for high-temperature performance in Yuma, Arizona. Tests demonstrated the superior performance of the charcoal grey ABS/PVC blend over a 100 percent PVC thermoplastic, which deformed under continuous high solar exposure. Materials evaluation also indicated excellent adhesion of the polyurethane encapsulant to the ABS/PVC thermoplastic.

The 28A is terminated at the protector block with a standard, two-pair D station wire cable pigtail. This use of D station wire presents a familiar interface to the telephone company installer. A pigtail design was selected during field trial to avoid the use of terminals. The terminals would have required an additional craft installation operation. Their presence also creates a potential corrosion site. A snap-on cover carried over from the 1119A filter design provides convenient storage for any excess pigtail.

The pigtail arrangement could not be used on the 1119A filter, however, because of the wide variation in mounting location on a telephone pole or a subscriber's house. In addition, the filter requires termination

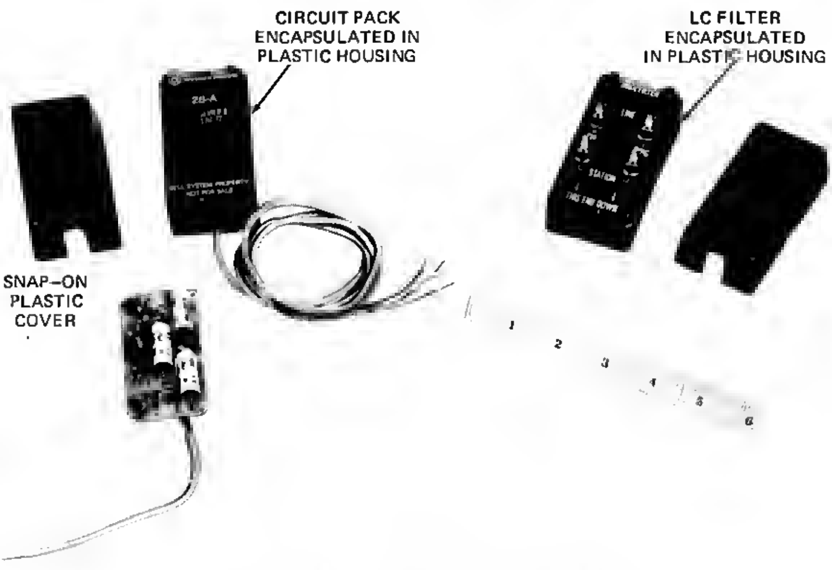

Fig. 29—Encapsulated electronic packages.

to drop wire (20 gauge copper coated steel) or station wire (22–24 gauge copper).

IV. ENVIRONMENTAL TESTING AND EVALUATION

The introduction of electronics in the outside plant requires both short-term and long-term product testing. Previous sections in this article have mentioned short-term testing programs conducted during product development that evaluated new materials and electronic component applications.

Detailed analysis and experimentation have also been done in the following areas:

(*i*) Solar absorptance of paints and thermal analyses of large electronic cabinets.

(*ii*) Modeling and experimental testing in real life environments of the temperature rise in small closures and outside plant pedestals and cabinets.

(*iii*) Moisture and humidity testing in outside plant electronic structures.

(*iv*) Effects of pollutants, dust and aerosols on wire spring relay components.

In addition to these short-term tests, long-term remote testing sites have been established in Thibodaux, Louisiana and Lake Quinault, Washington. Lake Quinault, at the edge of the Washington rain forest, provides a constantly high humidity (80 to 100 percent RH), with temperatures ranging from 30° to 90°F. Thibodaux provides a relative humidity of 75 to 90 percent with an annual temperature range of 25° to 95°F.

These sites have been used since early 1976 to evaluate terminals, printed wire board coatings, encapsulating compounds, and plastics.

The tests are a valuable aid to the laboratory environmental testing. Real-life effects of insects and direct and airborne debris provide insights into closure design, terminal layout, and printed wire board protection.

The Thibodaux site is shown in Fig. 30. Facilities are available for mounting closures on wall surfaces. Cabling is provided into a test shed for test access and powering. New electronic devices are installed at the sites to provide real time information on field performance.

V. PHYSICAL DESIGN FOR FUTURE LOOP ELECTRONICS

We have described in part some of the highlights and philosophies of loop electronics physical designs. With the advent of microprocessor chips and Large Scale Integration (LSI) technologies, lower cost, miniaturized loop electronic systems will permeate the urban and suburban

Fig. 30—Remote environmental test site, Thibodaux, Louisiana.

loop plant market. Greater flexibility will be required at remote terminal sites providing for increased suburban growth rates and greater rearrangement and change of customer lines. Furthermore, increased concentration of electronics serving suburban customers will require order of magnitude decreases in equipment size and more aesthetic packaging.

New package designs for the next generation of loop electronics systems are currently under exploratory evaluation.

VI. ACKNOWLEDGMENTS

Physical design and testing of loop electronic equipment and apparatus are the direct result of the combined efforts and talents of the technical staff and technical assistants of the Loop Electronics Facilities Department. We wish to acknowledge and thank the many staff members whose individual ideas, designs, and contributions form the backbone of work summarized in this article.

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